Using the NASA GEOS-5 MERRAero Aerosol Reanalysis to Understand the OMI OMAERUV Aerosol Products

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Objective and Approach

- Our objective is to investigate the sensitivity of the OMI OMAERUV aerosol retrieval algorithms to various aerosol parameters using synthetic data.

- Our approach is to use the GEOS-5 produced MERRAero aerosol reanalysis as a proxy for nature:
  - simulate the OMI radiance observations
  - provide these as inputs to OMAERUV
  - compare retrieved aerosol products to those directly calculated in model

- This kind of Observing System Simulation Experiment is a powerful tool to interrogate the retrieval algorithms we rely on for our science.
Aura and OMI

- Aura was launched July 15, 2004

- Positioned into A-Train constellation, about 1:30/13:30 local equator crossing time

- OMI
  - Ozone Monitoring Instrument
  - Joint Dutch-Finnish instrument
  - Wide-swath (~2600 km), hyperspectral (270 - 500 nm) imager (13 x 24 km² at nadir)
  - Measures ozone, trace gases, aerosols
  - Heritage with Total Ozone Mapping Spectrometer (TOMS)
OMI Aerosol Products

• There are at least two different aerosol retrieval algorithms in use
  - Multi-channel (19 wavelength) algorithm (Torres et al. 2002; Curier et al. 2008)
  - Two channel (354 and 388 nm) TOMS-like algorithm (OMAERUV, Torres et al. 2007)

• OMAERUV
  - UV measurements show sensitivity to aerosol absorption and altitude
  - Products include the aerosol index (AI), AOD, AAOD/SSA

Torres et al. 2007
The OMI Aerosol Index

Aerosol Index gives semi-quantitative information about the distributions of absorbing aerosols, sensitive to height and single scattering albedo.

Formally: the AI is the error in estimating observed 354 nm radiance from the 388 nm radiance assuming a purely molecular atmosphere bounded by a spectrally varying Lambertian surface;

In other words, it’s a measure of how the observed spectral contrast differs from what you’d expect in a molecular atmosphere.
Application to MERRAero

- MERRAero is GEOS-5 aerosol reanalysis
  - Replay MERRA meteorology, 0.5°
  - Assimilate MODIS-derived AOD (i.e., AOD is constrained) and adjust model aerosol mass

- OMI Observation Simulator
  - VLIDORT interface to model fields to simulate OMI radiances (inputs are OMI viewing geometry and surface reflectances)

- Comparison to OMI AI and retrieval products (AAOD) lets us improve unconstrained optical property assumptions (absorption)

Buchard et al. 2015
See also Hammer et al. ACP 2016 for adjustments to biomass burning aerosols and impact on photolysis rates
Our OMI Simulator

- MERRAero aerosol fields, optical properties, and atmospheric pressure profile
- OMI viewing geometry and spectral surface albedo
- Simulated OMI radiances and aerosol index
- OMAERUV calculated AI

- We assume cloud-free conditions
- Compare simulated to OMAERUV retrieved AI
- Do they agree?
Simulation of AI

- Given the same radiances, MERRAero and OMAERUV compute similar but different AI values.

- Possible explanations:
  - differences in AI formulation
  - differences in radiative transfer
  - differences in some other critical parameter
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  - GEOS-5 uses model pressure
  - OMAERUV assumes altitude-dependent but time-invariant pressure
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Sensitivity of AI to Pressure

All OMI pixels for June 2007 (n = 26.3M)

- 12% of points have $|\Delta(\text{OMAERUV - MERRAero})\text{AI}| > 0.2$ when OMAERUV uses own pressure
- 3% of points have $|\Delta(\text{OMAERUV - MERRAero})\text{AI}| > 0.2$ when OMAERUV uses MERRAero pressure
Difference in Monthly Mean AI

Monthly mean $\Delta AI$ comparison for June 2007

- Using MERRAero pressures, residual very small over ocean, with a seasonally varying latitude dependence
- Relatively larger but temporally stationary residual over land
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• Residuals correlate with mean surface pressure fields
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- Relatively larger but temporally stationary residual over land
- Residuals correlate with mean surface pressure fields
- Mean pressure correlates with topography
Marching east to west across this region, AI and LER differences grow larger as terrain altitude increases.

We found possibly significant difference between MERRAero and OMAERUV:
- MERRAero uses exact pressure profile to compute Rayleigh part of AI calculation
- OMAERUV uses precomputed values of Rayleigh calculation at two pressures (600 and 1000 hPa) and interpolates to actual pressure
Sensitivity to Radiative Transfer

\[ AI = -100 \cdot \log_{10} \left( \frac{I_{354}}{I_{354}^{\text{Ray}} \left( LER_{388}' \right)} \right) \]

\[ LER_{\lambda} = \frac{I_{\lambda} - I_{\lambda}^{\text{Ray}}}{T_{\lambda}^{\text{Ray}} + S_{\lambda}^{\text{Ray}} \left( I_{\lambda} - I_{\lambda}^{\text{Ray}} \right)} \]

\[ LER'_{388} = LER_{388} - (Alb_{388} - Alb_{354}) \cdot cf \]

Sensitivity analysis comparing MERRAero calculations versus OMAERUV shows implication of pressure interpolation.
Conclusions

• Demonstrated OMAERUV AI has imprint of assumed surface pressure on it; forcing to MERRAero surface pressure mostly resolves this, especially over water.

• Over land there is remaining AI residual which we think is related to topography indirectly by assumptions in OMAERUV Rayleigh lookup tables.

• Really just scratching the surface here: next step is to investigate the OMAERUV retrievals of AOD and SSA.